

Claims

What is claimed is:

1. A method of mixing a first stream of gas with a second stream of gas, comprising:
  - introducing a first stream of gas into a first stream manifold;
  - directing the first stream from the first stream manifold into a mixing chamber via a plurality of first stream passages flow coupled to the mixing chamber;
  - directing a second stream of gas into the mixing chamber via at least one second stream passage flow coupled to a first end of the mixing chamber;
  - forming a combined stream from the first and second streams;
  - gradually converging the combined stream; and
  - discharging the converged combined stream from the mixing chamber through a mixing chamber exit port.
2. The method of claim 1, further including:
  - expanding the converged combined stream downstream from the exit port.
3. The method of claim 1, further including:
  - introducing the second stream into a second stream manifold, and
  - wherein directing the second stream includes directing the second stream from the second stream manifold via a plurality of second stream passages flow coupled to the mixing chamber.
4. The method of claim 1, wherein the first stream is directed into the mixing chamber at the first end of the mixing chamber.
5. The method of claim 1, further including:

developing a substantially well-developed flow of the first stream within the plurality of first stream passages.

6. The method of claim 5, further including:  
developing a substantially well-developed flow of the second stream within the at least one second stream passage.

7. The method of claim 1, wherein the first stream is one of a stream of dilution air and a stream of exhaust gas from an engine, and the second stream is the other of the stream of dilution air and the stream of exhaust gas from an engine.

8. The method of claim 7, further including:  
sampling the combined stream for compliance with emission standards.

9. An apparatus for mixing a first and a second stream of gas, comprising:

a first stream manifold configured to receive the first stream of gas;

a first plurality of passages flow coupled to and extending from the first stream manifold; and

a mixing chamber having first and second ends, the mixing chamber flow coupled to the first plurality of passages and configured to receive the second stream of gas at the first end, the mixing chamber having an exit port at the second end and a cross-section adjacent the second end which gradually converges as the distance to the exit port decreases.

10. The apparatus of claim 9, further including:  
a secondary mixing region flow coupled to the mixing chamber downstream of the exit port, wherein the secondary mixing region has one of a

cross-section that gradually increases as the distance from the exit port increases and a cross-section that abruptly increases.

11. The apparatus of claim 10, further including:

a second stream passage flow coupled to the mixing chamber at the first end and adapted to discharge the second stream of gas into the mixing chamber,

wherein the first stream manifold, the plurality of passages, the second stream passage, the mixing chamber, and the secondary mixing region have smooth walls, and

wherein at least the second stream passage, the mixing chamber, and the secondary mixing region are insulated.

12. The apparatus of claim 9, further including:

a secondary mixing region flow coupled to the mixing chamber downstream of the exit port; and

a reservoir box flow coupled to the secondary mixing region at an end opposite the end which is flow coupled to the exit port.

13. The apparatus of claim 9, wherein the mixing chamber has internal wall surfaces formed of electro-polished, passivated, stainless steel.

14. The apparatus of claim 9, wherein the mixing chamber has smooth internal walls and no projections extending inwardly from the internal walls.

15. The apparatus of claim 9, further including:

a second stream manifold flow coupled to the second stream of gas; and

a second plurality of passages flow coupled to and extending between the second stream manifold and the mixing chamber,

wherein the first and second plurality of passages do not substantially extend into the mixing chamber.

16. The apparatus of claim 15, wherein the first and second stream manifolds are annular chambers.

17. The apparatus of claim 9, wherein the first plurality of passages are flow coupled to the mixing chamber at the first end of the mixing chamber.

18. A method of mixing an exhaust gas with a dilution gas, comprising:

providing a first gas which is one of an exhaust gas and a dilution gas;

providing a second gas which is the other of an exhaust gas and a dilution gas;

providing a mixing chamber having a first end and a second end and substantially smooth, unobstructed, internal walls therebetween;

introducing at least one substantially well-developed flow stream of the second gas into the mixing chamber at the first end;

introducing a plurality of substantially well-developed flow streams of the first gas into the mixing chamber in a pattern that is symmetric with respect to both a cross-section of the mixing chamber and the at least one stream of the second gas introduced into the mixing chamber; and

discharging a combined stream of the first gas and the second gas from the mixing chamber through a convergent cone region located at the second end of the mixing chamber into a secondary mixing region.

19. The method of claim 18, further including:

directing the first gas into a first gas manifold chamber prior to introducing the plurality of substantially well-developed flow streams of the first gas into the mixing chamber.

20. The method of claim 19, further including:

directing the second gas into a second gas manifold chamber prior to introducing the at least one substantially well-developed flow stream of the second gas into the mixing chamber, and

wherein the at least one substantially well-developed flow stream of the second gas is more than one.

21. The method of claim 18, further including:

using an engine to provide the second gas and sampling the combined stream in the secondary mixing region for compliance with emission standards.

22. A mixing chamber for mixing a first stream of gas with a second stream of gas, comprising:

an internal volume defined by a first end, a second end, and walls extending between the first and second ends, the second end having a gradually converging portion, such that no structure extends from the first end, from the second end, and from the walls into the internal volume;

a first inlet opening configured to receive the first stream of gas into the mixing chamber, the first inlet opening located at the first end;

a plurality of second inlet openings configured to receive the second stream of gas into the mixing chamber, the plurality of second inlet openings symmetrically positioned with respect to the first inlet opening; and

an exit opening configured to discharge a combined stream of gas formed from the first and second streams of gas from the mixing chamber, the exit opening located downstream of the gradually converging portion.

23. The mixing chamber of claim 22, wherein the first stream of gas is a stream of exhaust gas from an engine and the second stream of gas is a stream of dilution air.

24. The mixing chamber of claim 22, wherein the first end, the second end, and the walls have internal surfaces formed of electro-polished, passivated, stainless steel.